

# ITU-T Technical Report

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## YSTR.P2P-CC

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### Current state of P2P crowd charging platforms and corresponding market needs





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### **Summary**

A peer-to-peer (P2P) crowd charging system is a distributed system comprising ICT infrastructure provided by the general public (e.g., smartphones). The distributed resources of a P2P crowd charging system operate in a collaborative manner driven to perform energy sharing tasks by using their built-in power transfer modules. This work item will conduct a review of and provide an analysis of the current state of P2P crowd charging systems in terms of currently available technological solutions, ongoing research and recent and ongoing standardization activities in this area. The aim of the analysis will be to identify existing gaps and market needs in the area of P2P crowd charging systems.

### **Keywords**

Crowdsourced systems, peer-to-peer, Internet of things, energy sharing, smart cities.

### **Note**

This is an informative ITU-T publication. Mandatory provisions, such as those found in ITU-T Recommendations, are outside the scope of this publication. This publication should only be referenced bibliographically in ITU-T Recommendations.

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# Technical Report ITU-T YSTR.P2P-CC

## Current state of P2P crowd charging platforms and corresponding market needs

### 1 Scope

This Technical Report conducts a review of and provide an analysis of the current state of P2P crowd charging systems. More specifically, this Technical Report covers the following:

- Recent and ongoing standardization activities;
- Ongoing research;
- Currently available technological solutions;
- Existing gaps and market needs

### 2 References

- [ITU-T Y.4202] Recommendation ITU-T Y.4202 (2019), *Framework of wireless power transmission application service*.
- [ITU-T Y.4205] Recommendation ITU-T Y.4205 (2019), *Requirements and reference model of IoT-related crowdsourced systems*.

### 3 Definitions

#### 3.1 Terms defined elsewhere

This Technical Report uses the following terms defined elsewhere:

**3.1.1 device** [b-ITU-T Y.4000]: With regard to the Internet of things, this is a piece of equipment with the mandatory capabilities of communication and the optional capabilities of sensing, actuation, data capture, data storage and data processing.

**3.1.2 Internet of things (IoT)** [b-ITU-T Y.4000]: A global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on existing and evolving interoperable information and communication technologies.

NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled.

NOTE 2 – From a broader perspective, the IoT can be perceived as a vision with technological and societal implications.

**3.1.3 WPT base station** [ITU-T Y.4202]: A module transmitting electric power to the WPT device in a wireless manner.

**3.1.4 WPT charging** [ITU-T Y.4202]: The act of providing electric power to devices using WPT technology.

**3.1.5 WPT device** [ITU-T Y.4202]: An IoT device capable of receiving electric power from a WPT base station in a wireless manner

**3.1.6 crowd** [ITU-T Y.4205]: The term is used to collectively refer to the contributors (crowdsources) of a crowdsourced system, as well as to the resources that are provided to a crowdsourced system.

**3.1.7 crowdsourcing** [ITU-T Y.4205]: The practice of obtaining needed services, ideas, content or other system resources by soliciting contributions from a large, open and potentially undefined

group of people, rather than from employees, suppliers or identified experts through an online open call by providing incentives (financial, social, or entertainment) to all or a subset of those crowd members who participate in the crowdsourcing activity.

**3.1.8 crowdsourced systems** [ITU-T Y.4205]: Systems that employ crowdsourcing in order to augment their constituent infrastructure and the set of provided services or collected information.

### **3.2 Terms defined in this Technical Report**

None.

## **4 Abbreviations and acronyms**

This Technical Report uses the following abbreviations and acronyms:

DPP	Digital Product Passport
IoT	Internet of Things
P2P	Peer-to-Peer
QoE	Quality of Experience
WPT	Wireless Power Transmission

## **5 Introduction**

Recent technological advancements and corresponding trends have driven the rise of a new consumer IoT paradigm, namely the peer-to-peer (P2P) crowd wireless power transmission (WPT). On the one hand, high acceptance rates of smartphones, tablets, smartwatches, and other smart gadgets and wearables have led to an abundance of portable devices with significant communication and sensing capabilities. On the other hand, the increasing trend of open interface standards that define WPT using (inductive) charging over distances, such as the Qi standard [b-Qi] developed by the Wireless Power Consortium, enables the use of highly integrated P2P WPT platforms in the context of everyday use in different mobility use cases.

A number of P2P wired and WPT technologies have been built for different purposes by different companies from different countries, without considering their interconnectivity, for there are no specific international standards for P2P crowd WPT charging implementations available. For example, energy from two unknown users is difficult to share and infrastructures from different systems cannot be fully shared, resulting in a large number of unconnected energy silos at the edge of IoT networks. While some standardization activities focus on the low level of individual device technology, very few activities focus on a higher, system and service level, considering large-scale P2P WPT in large user crowds.

The related technology enablers have fuelled new energy sharing paradigms. A P2P crowd WPT system is a distributed system consisting of ICT infrastructure provided by the general public (e.g., smartphones). The distributed resources of a P2P crowd WPT system operate in a collaborative manner in order to perform energy sharing tasks by using their built-in power transfer modules. Commercialization of related individual technological features is already active. Products such as Samsung's Wireless PowerShare [b-PowerShare] or Huawei's Reverse Wireless Charging [b-Huawei] give the opportunity to users to share the device's remaining energy supplies directly with another device in a P2P manner. However, beyond the device-to-device paradigm and further into the crowd-wide modelling and implementation, a holistic methodological approach on how to define the requirements and how to model entire populations of P2P crowd WPT users is still missing. This Report conducts a review of and provides an analysis of the current state of P2P crowd charging systems in terms of currently available technological solutions, ongoing research and recent and ongoing standardization activities in this area.

## **6 Underpinning WPT technologies**

This clause gives a quick summary of the most popular WPT technologies that can support the crowd charging systems that are currently on the market.

### **6.1 WPT using inductive coupling**

#### **6.1.1 Inductive coupling**

WPT between two devices employing coils is made possible via inductive coupling. This technique uses electromagnetic induction and is frequently used in wireless charging mats for cellphones. A main coil-equipped transmitting device uses alternating current to produce a shifting magnetic field. A secondary coil on a receiving device, such as a smartphone, picks up this field and generates an alternating current that charges the battery. Effective coil alignment and closeness are essential for transfer. Applications for inductive coupling may be found in gadgets like smartphones and smartwatches, which are prized for their ease [b-Haerinia].

#### **6.1.2 Resonant inductive coupling**

An enhanced method of inductive coupling called resonant inductive coupling increases the effectiveness of power transfer by making use of resonant circuits. A transmitter coil and a receiver coil are often placed near together when using inductive coupling to transfer electrical energy between two items without physical touch.

### **6.2 Radio frequency (RF) energy harvesting**

RF energy harvesting transforms RF signals from the environment, such as cellular or Wi-Fi, into useful electrical energy. It uses an antenna or specialized module to pick up these signals, and then a rectifier circuit transforms them from AC to DC. Low-power gadgets can be powered by the energy directly or it can be stored in batteries. This technology uses RF signals from the surroundings and offers wireless, battery-free functioning to cut down on battery replacements. Though typically modest, gathered power makes this useful for low-power applications with low energy requirements [b-Lu].

### **6.3 Laser-based power transmission**

A technique known as laser-based power transmission makes it possible to transmit electricity wirelessly. This technology transfers electrical energy from one place to another without the need of actual wires or cables, as opposed to more conventional techniques. The underlying idea behind long-distance laser-based power transfer is the transformation of electrical energy into laser beams [b-Jankowiak].

In laser-based power transfer, electrical energy is transformed into laser light and then focused with the help of fine optics onto a receiver. At the receiver, photovoltaic cells (solar cells) catch the laser beam and use the photoelectric effect to transform its energy into electrical energy. Through this process, electrons are released to provide an electric current for powering equipment or storing energy. Laser-based transmission is adaptable for distant, space or dangerous locations since it provides wireless power supply without requiring physical connections. Research is being done to improve this technology's effectiveness, gearbox range, and safety [b-Duncan].

### **6.4 Microwave power transmission**

A technology known as microwave power transmission makes it possible to wirelessly transmit electricity across great distances using microwaves, a kind of electromagnetic radiation. In this process, electrical energy is transformed into microwaves, which are subsequently captured by rectifying antennas and transformed back into electrical energy.

Electromagnetic waves are used in microwave power transmission to move energy through antennas. Due to their low air absorption, microwaves with frequencies between 300 MHz and 300 GHz are commonly employed. A generator transforms power into microwaves, which are then sent through a transmitting antenna. The waves arrive at a rectenna at the receiving location, which is made up of a rectifier and a rectifying antenna that turns microwave energy into useful energy. This method makes it possible to transport electricity over great distances with little loss due to atmospheric interference, making it ideal for far-off applications such as solar power from space. However, safety precautions and laws to restrict transmitted power density for human safety are needed due to health dangers from high-power microwaves [b-Lin].

## **7 Ongoing research for crowd-wide P2P WPT methodologies**

[b-Nikolietseas] considers both lossless and lossy WPT, and then estimates the upper bound of time required to energy balance the whole crowd for both the scenarios. The report introduces three protocols for both scenarios with objectives targeting the minimization of energy loss and the time to reach energy balance. [b-Dhungana-1] combines WPT with wired charging and targets to find the maximum number of wired charging times that can be omitted through the use of P2P crowd WPT. [b-Madhja] investigates distributed crowd formation among mobile users with IoT devices of limited computational power that aim to achieve energy balance through P2P crowd WPT. [b-Raptis] introduces the impact of social networks on peer selection for P2P WPT and proposes two socially-motivated energy exchange protocols for the users explicitly focused on the social relationships of the users. [b-Dhungana-2] considers different energy sharing protocols with the objective of minimizing the energy loss in the energy balance process. [b-Ojha-1] addresses the challenges of user mobility jointly with the influence of the social impact of the user on the energy balancing timeline and considers multiple aspects of social information. [b-Ojha-2] takes one step further by considering wireless crowd charging scenarios in which individual devices wirelessly exchange power in the context of network-wide charging protocols with the aim of mitigating battery ageing and improving the quality of experience (QoE) of end users. In such crowd charging scenarios, the interoperability of WPT modules of different devices is crucial due to the innate openness that characterizes a crowd [ITU-T Y.4205], thus highlighting the need for corresponding P2P WPT standards.

## **8 Recent and ongoing standardization activities on WPT**

There are several recommendations and standards related to P2P WPT charging, which mainly focus on regulating P2P WPT charging at the low level (individual device technology) or standardizing the crowd level without the WPT charging component. Currently, a P2P crowd WPT standard focusing on large-scale crowds is missing.

[ITU-T Y.4202] defines a framework for WPT application service by describing concept, functional model, requirements, basic service flows and use cases. However, this recommendation does not consider (i) wired crowd charging, as it focuses on the wireless part (ii) social elements of the crowd charging process (such as online social network information), and (iii) P2P crowd WPT, as it focuses on wireless charging from an external power supplier and WPT base station.

[ITU-T Y.4205] introduces the concept of crowdsourced systems, as well as the reference model of IoT-related crowdsourced systems for the support of IoT applications and services to be provided via systems employing crowdsourcing principles. It addresses IoT-related crowdsourced systems in terms of functional requirements and the reference model as well as identifying relevant security, privacy and trust issues. However, this recommendation does not consider (i) the energy resources and the charging process, as it focuses on data as a resource, and (ii) the pure P2P administration, as the crowdsourcing process happens through a mediating crowdsourcing platform.

[b-ISO/IEC 15149-2] establishes a system for an in-band network, from which both wireless power transfer and data transmission are carried out simultaneously at the same frequency band. However,



this standard does not consider (i) charging service composition, as it focuses on PHY and MAC layer design, and (ii) pure P2P administration, as the charging process is highly centralized.

## **8.1 Qi**

For low-power gadgets like smartphones, smartwatches and earphones, the Qi wireless charging standard has become quite popular. The Wireless Power Consortium created Qi, which is based on the idea of inductive coupling. Users can charge their smartphones wirelessly without the inconvenience of wires thanks to the standard, which guarantees compatibility and interoperability across various devices and charging pads. Major device makers accept Qi, making it the industry de facto standard for wireless charging in consumer devices. With Qi, customers just need to set their compatible devices on a Qi-enabled charging pad for the power transfer process to begin thanks to an electromagnetic interaction between the coils in the charging pad and the device. The adoption of Qi standard has streamlined the WPT experience and has gradually become a prevalent functionality in numerous modern devices [b-Qi].

## **8.2 AirFuel**

A cooperative organization dedicated to improving and promoting wireless charging technologies, particularly inductive and resonant wireless charging, is the AirFuel Alliance. This consortium's main goal is to develop interoperability and standardization for medium- to high-power applications, including electric cars, tablets and laptops. The AirFuel Alliance works to provide a standard architecture that enables smooth integration and interoperability among various devices and charging systems by bringing together industry leaders and stakeholders. This endeavour at standardization makes sure that users can easily wirelessly charge their devices using a variety of infrastructure and charging pads that are compatible. The AirFuel Alliance is essential in advancing wireless charging technologies across a variety of industries, offering a practical and effective way to charge devices without using cables or other physical connections [b-AirFuel Alliance].

## **8.3 Powermat**

Powermat is a wireless charging technology that transmits electricity via inductive coupling. Users can simply charge their gadgets without the usage of wires thanks to its widespread deployment at public charging stations. The Qi standard, which is the most extensively used wireless charging standard, is supported by Powermat products. This interoperability is made possible via the use of adapters that Qi-enabled devices may attach to, making it possible for them to function with Powermat charging stations. With Powermat, customers only need to set their compatible devices on a Powermat charging pad for the wireless power transfer to begin thanks to an inductive interaction between the coils in the charging pad and the device. Using this technology, people may easily access wireless charging capabilities in a variety of public places, including stadiums, coffee shops, and airports [b-Powermat].

## **8.4 Rezence**

The Alliance for Wireless Power (A4WP) has created a wireless charging standard called Rezence. As opposed to conventional inductive charging, it makes use of resonant inductive coupling technology, which enables effective power transmission over greater distances. Rezence's main benefit is its capacity to accommodate simultaneous charging of several devices positioned on the charging surface. To do this, a resonant magnetic field is produced, allowing several receiving devices to couple with it and receive electricity at the same time. Rezence enables customers to charge a variety of gadgets, including smartphones, tablets and wearables, by just setting them down on a charging surface or pad. With the use of this technology, consumers may charge their gadgets conveniently and adapters or additional charging cables are not required. The development of Rezence by the A4WP contributes to the advancement of WPT and gives users a standardized way to efficiently charge and multiple devices [b-AWP].

## **9 Policy-making at a regional level**

As identified in clause 11.1, one of the potential existing market gaps for P2P crowd WPT adoption is that of battery ageing mitigation with intelligent WPT. This gap is directly related to regional policymaking initiatives such as the Battery Passport technology of the EU. The Battery Passport is a technological enabler which makes the stakeholders in the supply and value chains capable of sharing information about a battery and its history to maximize safety and lifetime and facilitate responsible recycling at end of life. The EU introduced a new Regulation on batteries on 10 December 2020 [b-EC-1]. This Regulation aims at making sure that the batteries distributed in the EU market are safe and sustainable across their whole lifetime.

Moreover, in the EU realm and beyond, reliance on international trade for important resources, such as energy materials, can be sometimes seen as a vulnerability, because some of the identified dependencies could be considered of potential strategic importance. Also, The EU circular economy action plan mentions energy efficiency for consumer products and construction [b-EC-2]. Increasing energy efficiency of the whole energy system and applying circular principles to the energy technologies throughout their entire life cycle is considered one of the top priorities. A key technical enabler in this direction is the Digital Product Passport (DPP), which is also provisioned in [b-EC-2]. DPPs will provide an ICT infrastructure that will allow the collection and access of data pertaining to manufacturing and use of products available in EU throughout their entire lifecycle. The aim of DPPs is to use this data to support the introduction of circular practices in decision-making (e.g., regarding upcycling or repurposing materials). The battery ageing mitigation concepts with intelligent WPT can reveal a crowd-wide battery health optimization perspective, which can in turn provide guidelines and definitions on how to maximize the battery lifetime, boost circularity and indirectly reduce dependency on imported battery materials.

## **10 Currently available commercial solutions for P2P WPT**

Samsung's Wireless PowerShare technology [b-Samsung] can enable IoT devices to charge other IoT devices. A user activates the functionality on the notification panel of a device, then places the other device on the centre of the first device with their backs facing. The manufacturer also notes that the WPT efficiency depends on the distance between the charging coils of the IoT devices. The IoT device to be charged must operate with the Qi standard [b-Qi]. The manufacturer notes that products from other manufacturers can also be charged, and that different devices may perform the WPT process at different speeds.

Huawei's Reverse Wireless Charging technology [b-Huawei] can enable IoT devices to charge other IoT devices. The Reverse Wireless Charging is automatically disabled when the user device's battery level is lower than 20 per cent. The manufacturer notes that the WPT process is typically slower than conventional charging methods, and consequently, Reverse Wireless Charging would be more suitable for cases of emergency. Also, the manufacturer notes that for a fully charged device, standard chargers are recommended. The IoT device to be charged must operate with the Qi standard [b-Qi]. The Reverse Wireless Charging technology can only function when both devices are turned on and only on a P2P manner from one device to another.

## **11 Existing gaps and market needs**

The following clauses present some representative commercial use cases in which P2P crowd WPT can be proven a key enabler for market establishment and growth.

### **11.1 Battery ageing mitigation with intelligent WPT**

Battery technology upgrades have been advancing much slower than other electronic components, and, therefore, batteries are usually seen as the least energy-efficient and the most design- and performance-limiting part of IoT devices [b-Armand]. The gradual decline of battery capacity,

defined in the literature as battery ageing [b-Proebstl], is a core problem for the energy aspects of IoT devices. Battery ageing is one of the main energy bottlenecks for the IoT device lifetime. The existing battery ageing mitigation methodologies only partially leverage the available set of options to extend battery life. In this regard, P2P crowd WPT with intelligent battery ageing mitigation could enable a prolonged device lifetime. The few recent existing methodologies aim at individualized battery ageing mitigation and user profiling. With no information about other users in the crowd, or energy sharing technologies such as P2P crowd WPT, these methods fail to maximize the potential of intelligent charging to the fullest. This identified gap can only be addressed by employing new methodologies which:

1. Consider the particular parameters of the (fundamental) human factor of the crowd and take into account the sociotechnical factor by addressing the user QoE, with respect to extending battery life through battery ageing mitigation.
2. Design pervasive and crowd-wide protocols with battery ageing mitigation for P2P crowd WPT.
3. Consider significant characteristic phenomena from the physical world, in a fine-grained manner in the battery lifetime modelling process, also in relation to battery ageing parameters.

## **11.2 Unmanned aerial vehicles (UAVs)**

The development of holistic algorithmic crowd charging frameworks that address the diverse and dynamic energy needs of urban populations can further promote the adoption of WPT technologies. Such frameworks leverage the collective power of numerous interconnected devices to create a resilient energy network, capable of optimizing power distribution in real-time [b-Raptis]. The foundation of such frameworks lies in advanced algorithms that can dynamically allocate energy resources based on real-time data from a multitude of IoT devices scattered throughout the city. These algorithms are designed to consider factors such as device battery levels, usage patterns and the spatial distribution of devices. By continuously analysing this data, the framework can predict energy demands and direct surplus energy from devices with higher battery levels to those with lower levels, thereby maintaining a balanced energy distribution across the network. This can not only enhance the overall efficiency of the energy system but also extend the battery life of individual devices through intelligent energy management.

Moreover, the integration of unmanned aerial vehicles (UAVs) into this framework offers a complementary approach to WPT in urban settings. UAVs equipped with WPT capabilities can serve as mobile energy hubs, delivering power to devices in areas where traditional charging infrastructure is limited or non-existent. These UAVs can be deployed on-demand to recharge devices on the go, ensuring the continuous connectivity and functionality of critical IoT systems. UAV-based WPT operates through precise navigation and energy transfer protocols [b-Ojha-3]. UAVs utilize advanced positioning systems to identify and approach target devices with low battery levels. Once in proximity, they establish a wireless power transfer link using technologies such as resonant inductive coupling or laser-based power transfer. The efficiency of this process can be maximized through real-time adjustments in UAV positioning and power transfer parameters, ensuring optimal energy delivery with minimal loss. The integration of UAVs within a holistic crowd charging framework necessitates robust coordination and management strategies. This includes the development of sophisticated control algorithms that can manage the fleet of UAVs, optimizing their flight paths, energy levels and charging schedules to meet the dynamic energy demands of the city.

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